

# DESIGN AND FEA OF A HYBRID COMPOSITE DRIVE SHAFT FOR AN AUTOMOBILE

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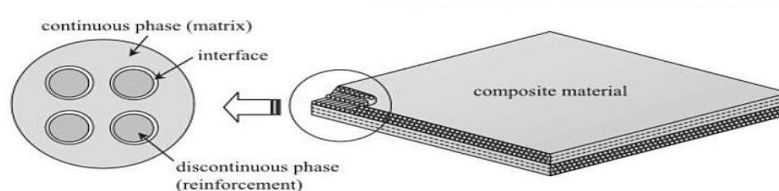
## ABSTRACT

Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and are not soluble in each other. The main difference between a composite and an alloy is that constituent materials are insoluble in each other and the individual constituents retain those properties, where as in alloys, constituent materials are soluble in each other and form a new material which has different properties from its constituents. One constituent is called reinforcing phase and the one in which the reinforcing phase is embedded is called matrix.

**Keywords:** Composite, Macroscopic Level, Ultimate Load, Reinforcing

## I INTRODUCTION

Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and are not soluble in each other. The main difference between a composite and an alloy is that constituent materials are insoluble in each other and the individual constituents retain those properties, where as in alloys, constituent materials are soluble in each other and form a new material which has different properties from its constituents.



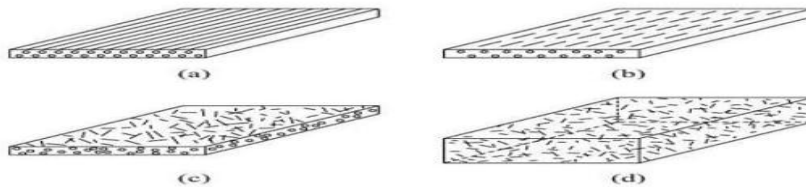
## Advanced composites

Advanced composite materials are referred to those composite materials developed and used in the aerospace industries. They usually consist of high performance fibers as reinforcing phases and polymers or metals as matrices. The fibers have very high stiffness and strength. However, the key to taking high properties of fibers is to embed them in a surrounding matrix, which acts as a support for the fibers, transfer applied loads to the fibers, and to form useful structural shapes.

### Hybrid Composites

Hybrid composites are usually multi-layered (laminate) with mixed fibers. The fibers may be mixed in a ply or layer by layer and these composites are designed to benefit from different properties of the fibers employed. For example, graphite-epoxy laminae are used with Kevlar-49 epoxy laminae to create wing-to-body fairings for the Boeing 757 and 767.

## II TYPES OF COMPOSITES



- (a) Unidirectional lamina (ply) with continuous fiber
- (b) Unidirectional lamina with discontinuous fiber
- (c) Random orientation in a plane
- (d) 3-D random orientation short fibers whisker

### 2.1 Matrix of FRC

The primary functions of the matrix are to transfer stresses between the reinforcing fibers (hold fibers together) and protect the fibers from mechanical and/or environmental damages. A basic requirement for a matrix material is that its strain at break must be larger than the fibers it is holding.

### 2.2 Modifiers of FRC

The primary functions of the additives (modifiers, fillers) are to reduce cost, improve workability, and/or impart desired properties.

- **Cost Reduction:**  
Low cost to weight ratio, may fill up to 40% (65% in some cases) of the total weight
- **Workability Improvement:**  
Reduce shrinkage  
Help air release  
Decrease viscosity  
Control emission

## 2.3 Advantages of Composites

Composites offer many advantages over other materials. Within Aerospace, Automobile and Marine markets, where exceptional performance is required but weight is critical, composites continue to grow in importance. The many advantages of composites may be summarized as:

1. Stronger and stiffer than metals on a density basis
2. For the same strength, lighter than steel by 80% and aluminum by 60%
3. Superior stiffness-to-weight ratios

## 2.4 Applications of Composites

The common applications of composites are extending day by day. Nowadays they are used in medical applications too. The other fields of applications are,

- **Automotive:** Drive shafts, clutch plates, engine blocks, push rods, frames, Valve guides, automotive racing brakes, filament-wound fuel tanks, fiber Glass/Epoxy leaf springs for heavy trucks and trailers, rocker arm covers, suspension arms and bearings for steering system, bumpers, body panels and doors.
- **Aircraft:** Drive shafts, rudders, elevators, bearings, landing gear doors, panels and floorings of airplanes etc.
- **Space:** Payload bay doors, Remote manipulator arm, High gain antenna, Antenna ribs and Struts etc.
- **Marine:** Propeller vanes, Gear cases, Condenser shells, Valves & strainers, Fans & blowers
- **Chemical Industries:** Composite vessels for liquid natural gas in alternative fuel vehicles, racked bottles for fire services, mountain climbing, under ground storage tanks, ducts and stacks etc.
- **Electrical & Electronics:** Structures for overhead transmission lines for railways, Power line insulators, Lighting poles, Fiber optics tensile members etc.
- **Sports Goods:** Tennis rackets, Golf club shafts, Fishing rods, Bicycle framework, Hockey sticks, Surfboards, Helmets and others

## III. EXPERIMENTATION

In the process of designing a vehicle, one of the most important objectives is the conservation of energy and the most effective way to obtain this goal is the reduction of weight of the vehicle. There is almost a direct proportionality between the weight of the vehicle and its fuel consumption, particularly in city driving. 3.1

### 3.1 Specification of Problem

Almost all automobiles (which correspond to design with rear wheel drive and front engine installation) use a drive shaft for the transmission of motion from the engine to the differential. An automotive propeller shaft, or drive shaft, transmits power from the engine to differential gears of a rear wheel-driving vehicle. The static torque transmission capability of the propeller shaft for passenger cars, and small truck and vans should be larger than 3500 Nm and the fundamental bending natural frequency should be higher than 8000rpm to avoid whirling vibration.

### 3.2 Aim and Scope of the Work

The project aims to reduce the weight of the drive shaft assembly by using advanced composite materials. For this project work, the drive shaft of a Toyota Qualis was chosen. The modeling of the drive shaft assembly was done using CATIA V5R16. A shaft has to be designed to meet the stringent design requirements for automobiles.

### 3.3 Problem Formulation

#### 3.3.1 Actual Problem

However, in reality the drive shaft is not a simple hollow cylinder, but a complex assembly of a number of parts. This assembly of parts which makeup the drive shaft assembly was modeled using CATIA software. The drive shaft of Toyota Qualis was chosen for determining the dimensions. Using these dimensions, the entire assembly was created in CATIA.

#### 3.3.2 Description of the Problem

The fundamental natural bending frequency for passenger cars, small trucks, and vans of the propeller shaft should be higher than 6,500 rpm to avoid whirling vibration and the torque transmission capability of the drive shaft should be larger than 3,500 Nm. The drive shaft outer diameter should not exceed 100 mm due to space limitations.

S. No	Name	Notation	Units	Value
1	Ultimate Torque	$T_{max}$	Nm	3500
2	Maximum Speed of shaft	$N_{max}$	rpm	6500
3	Maximum Diameter of the shaft	D	mm	100

### 3.3 Material Properties : Steel

The standard material properties of steel are given as follows

Mechanical properties	Symbol	Units	Steel
Young's Modulus	E	GPa	207.0
Shear modulus	G	GPa	80.0
Poisson's ratio	$\nu$	-----	0.3
Density	$\rho$	Kg/m <sup>3</sup>	7600
Yield Strength	$S_y$	MPa	370
Shear Strength	$S_s$	MPa	--

### 3.4 Material Properties for Boron/Epoxy

Fiber: Boron

Density = 2600 kg/m<sup>3</sup>

Young's Modulus = 385 Gpa

Poisson's Ratio = 0.21

Boron/Epoxy Composite Properties:

Density of the Composite = 2249 kg/m<sup>3</sup>

Matrix: Epoxy

Density = 1300 kg/m<sup>3</sup>

Young's Modulus = 3 Gpa

Poisson's Ratio = 0.34

Property	Units	Stacking Sequence		
		[0/30] <sub>8s</sub>	[□45] <sub>8s</sub>	[0/90] <sub>8s</sub>
Longitudinal Modulus (E11)	Gpa	281.86	281.86	281.86
Transverse Modulus (E22)	Gpa	10.88	10.88	10.88
Shear Modulus (G12)	Gpa	4.1234	4.1234	4.1234
Young's Modulus in X- Direction (E <sub>xx</sub> )	Gpa	281.86	33.66	155.7
Young's Modulus in Y- Direction (E <sub>yy</sub> )	Gpa	10.88	27.12	137.59
Major Poisson's Ratio (V <sub>xy</sub> )		0.2451	0.2451	0.2451

Minor Poisson's Ratio ( $V_{yx}$ )	0.0095	0.0095	0.0095
Shear Modulus in XY Direction ( $G_{xy}$ ) Gpa	4.1234	67.4925	4.1235

**Table 3.3 Material Properties of Boron/Epoxy Composite**

**3.5 Material Properties for Kevlar/Epoxy**

Fiber: Kevlar 49

Density = 1440 kg/m<sup>3</sup>

Young's Modulus = 130 Gpa

Poisson's Ratio = 0.34

Kevlar/Epoxy Composite Properties:

Matrix: Epoxy

Density = 1300 kg/m<sup>3</sup>

Young's Modulus = 3 Gpa

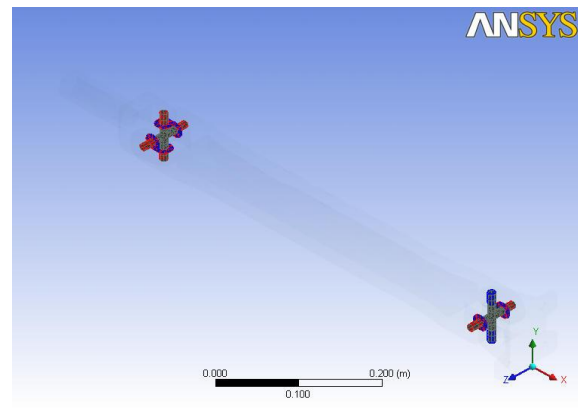
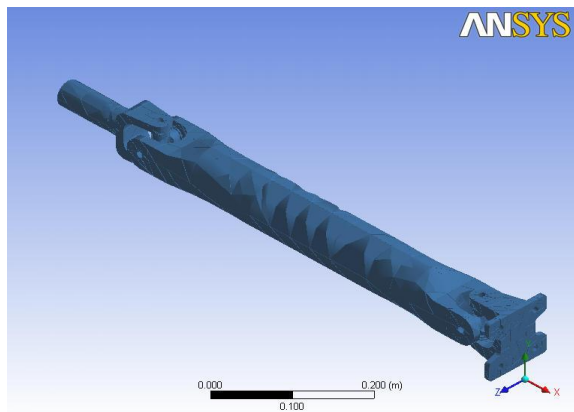
Poisson's Ratio = 0.34

Property	Units	Stacking Sequence		
		<u>[0/30]<sub>8S</sub></u>	<u>[□45]<sub>8S</sub></u>	<u>[0/90]<sub>8S</sub></u>
Longitudinal Modulus (E11)	Gpa	95.71	95.71	95.71
Transverse Modulus (E22)	Gpa	10.45	10.45	10.45
Shear Modulus (G12)	Gpa	4.03	4.03	4.03
Young's Modulus in X- Direction (E <sub>xx</sub> )	Gpa	95.71	14.12	56.33
Young's Modulus in Y- Direction (E <sub>yy</sub> )	Gpa	10.46	14.14	50.59
Major Poisson's Ratio ( $V_{xy}$ )		0.34	0.34	0.34
Minor Poisson's Ratio ( $V_{yx}$ )		0.037	0.037	0.037
Shear Modulus in XY Direction ( $G_{xy}$ )	Gpa	4.03	25.08	4.03

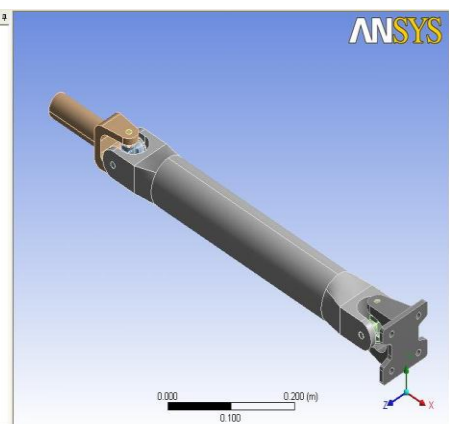
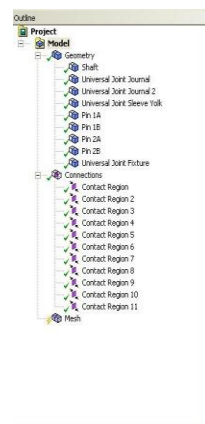
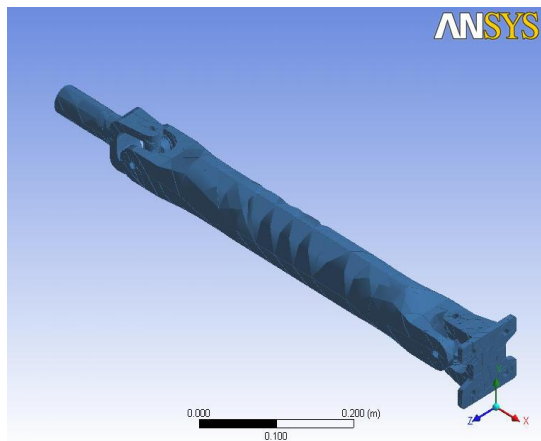
Density of the Composite = 1402.2 kg/m<sup>3</sup>

### 3.6 ANALYSIS

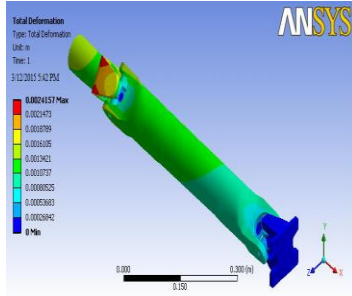
Since the domain for analysis is a complex assembly of a number of parts, ANSYS 11.0 Workbench was chosen for performing the analysis. The proper connection between each part of the assembly and the subsequent connectivity of mesh is the key criteria for getting proper load transfers throughout the assembly. The Workbench module of ANSYS 11.0 does not require the explicit specification of element types by the user, depending upon the assembly, the element types are chosen by the solver to get the best possible results.



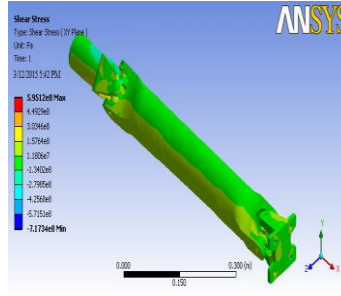
## TORSIONAL ANALYSIS



### 3.6.1 Steel



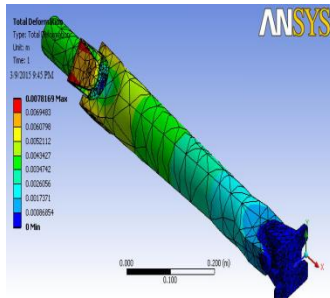
Deformation



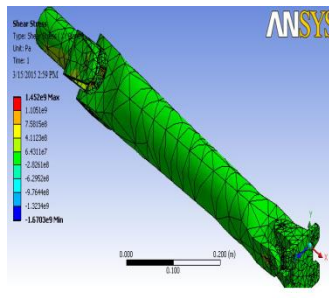
Shear Stress

### 3.6.2 Boron/Epoxy

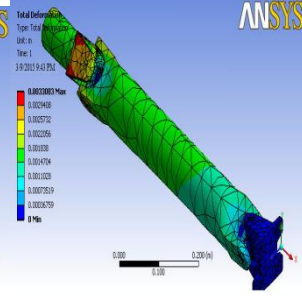
Ply Orientation:  $[0/30]_8$  s:



Deformation



Shear Stress

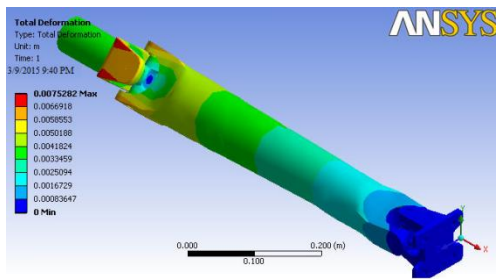


Deformation

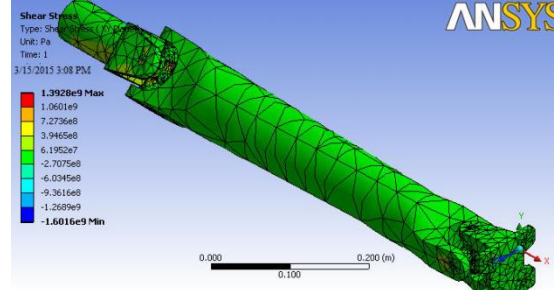


Shear Stress

Ply Orientation:  $[+/-45]_8$  s:



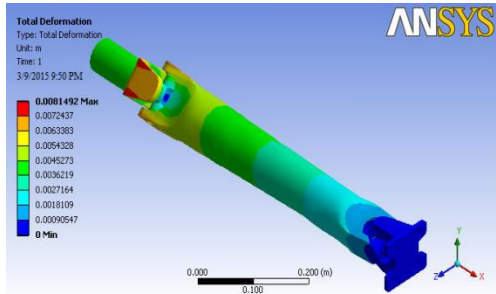
Deformation



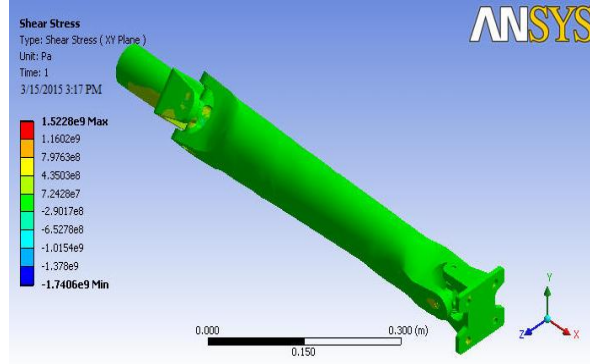
Shear Stress

### 3.6.3 Kevlar/Epoxy

Ply Orientation:  $[0/30]_8 s$

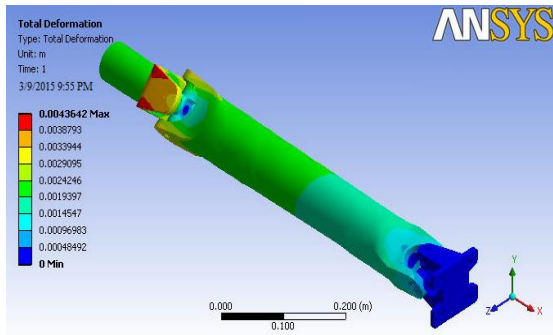


Deformation

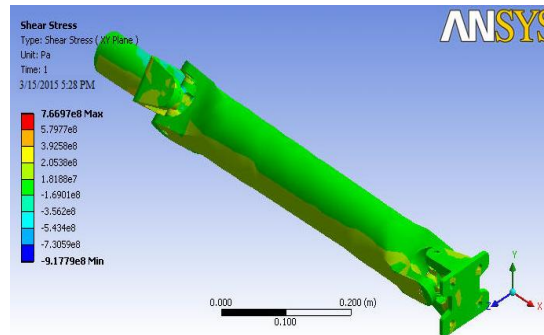


Shear Stress

Ply Orientation:  $[+/-45]_8 s$

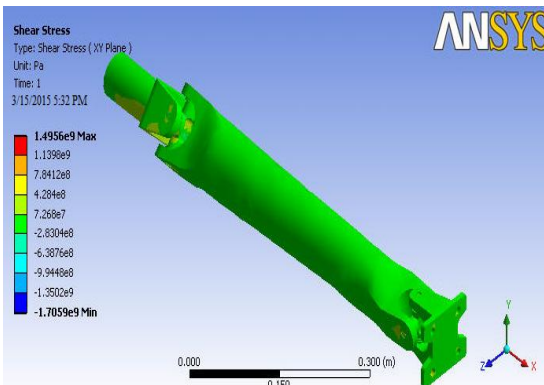
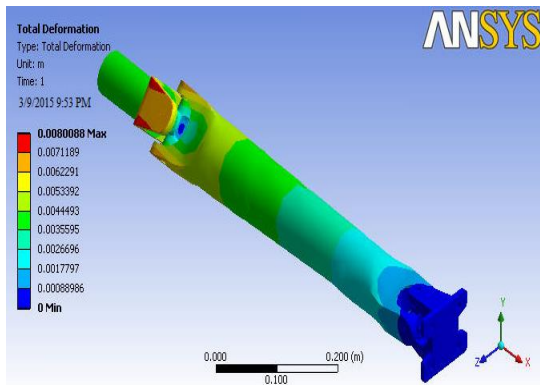


Deformation



Shear Stress

Ply Orientation:  $[0/90]_8 s$



## IV RESULT AND OBSERVATIONS

### 4.1 Torsional Analysis Results

Material Used	Stress (Pa)	Deflection (m)	Shear Stress (Pa)	Weight (Kg)
Steel (SM45C)	2.85 e9	0.0024	5.95 e8	14.08
Boron/Epoxy [0/30] <sub>8s</sub>	8.97 e9	0.0078	1.45 e9	6.20
<b>Composite</b> [±45] <sub>8s</sub>	3.83 e9	0.0033	7.31 e8	
	[0/90] <sub>8s</sub>	8.66 e9	0.0075	1.39e9
Kevlar/Epoxy [0/30] <sub>8s</sub>	9.32 e9	0.0081	1.52 e9	4.96
<b>Composite</b> [±45] <sub>8s</sub>	5.08 e9	0.0043	7.66 e8	
	[0/90] <sub>8s</sub>	9.17 e9	0.0080	1.49 e9

### 4.2 Harmonic Analysis Results

Material Used	Maximum Amplitude occurs at (Hz)	Deformation (m)
Steel (SM45C)	700	0.00012
Boron/Epoxy [0/30] <sub>8s</sub>	800	0.0078
<b>Composite</b> [±45] <sub>8s</sub>	700	0.0009
	[0/90] <sub>8s</sub>	900
Kevlar/Epoxy [0/30] <sub>8s</sub>	900	0.00067
<b>Composite</b> [±45] <sub>8s</sub>	730	0.0043
	[0/90] <sub>8s</sub>	800

## V CONCLUSION

The presented work was aimed at reducing the fuel consumption of the automobiles in particular or any machine, which employs drive shafts, in general. This was achieved by reducing the weight of the drive shaft with the use of composite materials. The Drive shaft of a Toyota Qualis was chosen for determining the dimensions, which were then used for creating a model in CATIA V5R17. The material properties of composites were determined based on Classical Lamination Theory using a C Code. Being a complex assembly of a number of parts, it had to be analyzed in ANSYS 11.0 Workbench. A total of five materials were chosen for the comparative analysis, including steel, which was used for reference. The Composites were analyzed at three different ply orientations.

The usage of composite materials has resulted in considerable amount of weight saving in the range of 65% to 54% when compared to conventional steel shaft. Taking into consideration the weight saving, deformation, shear stress induced and resonant frequencies it is evident that Kevlar/Epoxy composite has the most encouraging properties to act as the replacement for steel out of the considered five materials. And the best suitable ply orientation is  $[+/- 45^\circ]$ .

## REFERENCES

- [1]. Axiomatic design and fabrication of composite structures: Applications in Robots, Machine Tools, and Automobiles - By Dai Gil Lee, Nam Pyo Suh – Oxford University Press
- [2]. Mechanics of laminated composite plates and shells: theory and analysis - by Junuthula Narasimha Reddy
- [3]. “Design Data” – Databook of Engineers. – P.S.G. College.
- [4]. Optimal Sizing and Stacking Sequence of Composite Drive Shafts - Thimmegowda rangaswamy, Sabapathy Vijayarangan
- [5]. Polymer Matrix Composites In Driveline Applications -Dr Andrew Pollard, GKN Technology, Wolverhampton, UK
- [6]. Static Torsion Capacity of a Hybrid Aluminum Glass Fiber Composite Hollow Shaft - S.A. Mutasher, B. B. Sahari and A. M. S. Hamouda, S.M. Sapuan
- [7]. Automotive Composite Driveshafts: Investigation Of The Design Variables Effects - M. A. Badie, A. Mahdi, A. R. Abutalib, E. J. Abdullah and R. Yonus
- [8]. Static and dynamic characteristics of a hybrid composite drive shaft - S A Mutasher, B B Sahari, A M S Hamouda, and S M Sapuan
- [9]. Beardmore, P., et al. The Potential for Composites in Structural Automotive Applications J. of Composites Science and Technology 26 1986
- [10]. Beardmore, P. Composite Structures for Automobiles Comp. Structures 5 1986.